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Photon Interaction Data for ENDF/B-VI

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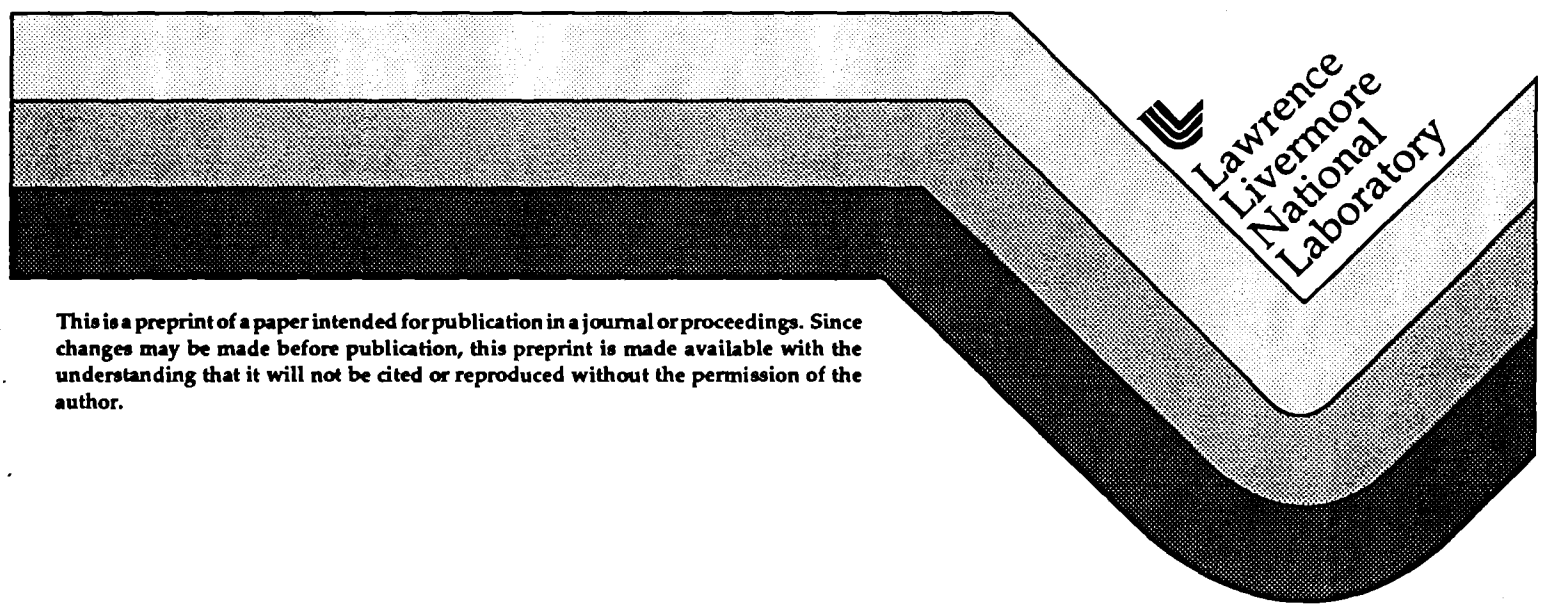

DISCLAIMER

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Abstract

The ENDF/B-VI photon interaction library includes data for the elements hydrogen (Z=1) through fermium (Z=100) over the energy range 10 eV to 100 Mev. This library contains data to meet the needs of traditional photon transport methods. However, this library also contains data that can be used to perform much more detailed transport calculations. This paper describes the contents of this library and how it can be used for both traditional and more detailed transport calculations.

Introduction

Compared to earlier ENDF/B versions of the photon interaction data, the new ENDF/B-VI library contains much more detail; this is the first extension of the contents of the ENDF/B photon interaction data base since the inception of ENDF/B over twenty years ago.

This new library is designed to allow us to perform much more detailed photon transport calculations. At the same time care has been exercised to insure that it can still be used to perform traditional calculations, where additional details in transport are judged by the user not to be required.

Traditional ENDF/B Photon Interaction Data

Traditionally the data included in the ENDF/B photon interaction data base has been sufficient to describe the interaction of primary photons with matter. The data traditionally contained in this data base included,

1) Cross Sections: for coherent and incoherent scattering, pair production and photoelectric absorption
2) Form and scattering factors: used to describe the angular distribution of coherent and incoherent scattered photons

Although this data is sufficient to describe the interaction of primary photons, it is not adequate to uniquely define the emission of secondary photons following photoelectric effects, e.g., fluorescence. Nor did it include the effect of anomalous scattering, which significantly effects coherent scattering near and below the photoelectric absorption edges. Lastly this data did not differentiate between pair and triplet production.

Additional ENDF/B-VI Photon Interaction Data

In addition to the data traditionally included, this data base now contains,

1) Cross Sections: for each photoelectric subshell, pair and triplet production cross sections, a coherent cross sections accounting for anomalous scattering.
2) Anomalous scattering factors: used in combination with form factors to describe the angular distribution of coherently scattered photons.

To illustrate the increased detail that this library includes Fig. 1 shows the traditional lead cross sections: essentially we need merely four types of cross sections to describe coherent and incoherent scattering, photoelectric absorption and pair production. Fig. 2 illustrates the lead photoelectric subshell cross sections included in the ENDF/B-VI library. Is it important to have this additional detail?

Traditionally when a photoelectric event occurs all of the energy is assumed to be deposited at the point of the event. Fig. 3 illustrates that in fact when a photon undergoes photoelectric absorption just above the K edge in lead, 87.9 % of the energy is re-emitted as fluorescence x-rays just below the K edge, where the cross section is quite small - allowing these x-rays to be quite penetrating.

Is anomalous scattering important. From fig. 1 we can see that with anomalous scattering included the coherent scattering scattering cross section at low energy is decreasing and near 10 eV in lead it is about 10 barns. In contrast, without including anomalous scattering is about 4480 barns - a factor, not per-cent, an actual factor of 448 times too large.

This data base is documented in ref. 1 and 2 and is currently available in the ENDF/B-VI format from data centers throughout the world.

Related Data Bases

This data base is designed to be used with two of our other data bases to allow coupled photon-electron transport calculations in order to completely account for the emission of all secondary photons, as well as a more detailed description of energy, dose, etc. deposition within media. These two data bases include: 1) an electron interaction data base, covering the same range of elements (Z = 1 to 100) and energy range (10 eV to 100 GeV) as our photon interaction data base; 2) an atomic relaxation data base, to describe the relaxation of atoms back to neutrality following any ionizing event; during the relaxation, photons (fluorescence) and electrons can be emitted

by the atom, which should be considered in a photon-electron calculation, or even in a basic photon transport calculation. Fig. 4 illustrates the lead electron ionization subshell cross sections contained in our electron interaction library. Fig. 3 illustrates the radiative and non-radiative emission due to a vacancy in the K shell of lead: these results were calculated using our atomic relaxation data base.

These two data bases are documented in ref. and 4, listed below. Unfortunately, as yet the ENDF/B system does not include formats to handle either electron interaction or atomic relaxation data; as such these two data bases are only available in the Livermore ENDL format.

Conclusions

In this paper we described details of the ENDF/B-VI photon interaction data base, with emphasis on satisfying the needs of two different groups of users: 1) Those who would like to use this data in the traditional sense, without including additional details in the calculations - we have taken care to insure that this can still be done, and 2) Those who would like to extend their calculations to include more details in their photon (and if desired, coupled electron) transport calculations.

This library and the related electron and relaxation libraries are documented in refs. 1 thrugh 4. This library is currently available from data centers throughout the world. The additional electron and relaxation libraries are available from the authors.

References

1) "Tables and Graphs of Photon-Interaction Cross Sections from 10 eV to 100 GeV Derived from the LLNL Evaluated Photon Data Library (EPDL)", Part A: Z = 1 to 50, Part B: Z = 51 to 100, UCRL-50400, Vol. 6, Rev. 4, Lawrence Livermore National Laboratory, Livermore, CA, (October 1989), by D. E. Cullen, et.al.

2) "The 1989 Livermore Evaluated Photon Data Library (EPDL)", UCRL-ID-103424, Lawrence Livermore National Laboratory (March 1990), by D. E. Cullen, S.T. Perkins and J.A. Rathkopf.

3) "Tables and Graphs of Atomic Subshell and Relaxation Data Derived from the LLNL Evaluated Atomic Data Library (EADL), Z = 1-100", UCRL-50400, Vol. 30, Lawrence Livermore National Laboratory, Livermore, CA, (October 1991), by S. T. Perkins, et.al.

4) "Tables and Graphs of Electron-Interaction Cross Sections from 10 eV to 100 GeV Derived from the LLNL Evaluated Electron Data Library (EEDL), Z = 1-100", UCRL-50400, Vol. 31, Lawrence Livermore National Laboratory, Livermore, CA, (November 1991), by S. T. Perkins, D. E. Cullen and S. M. Seltzer.

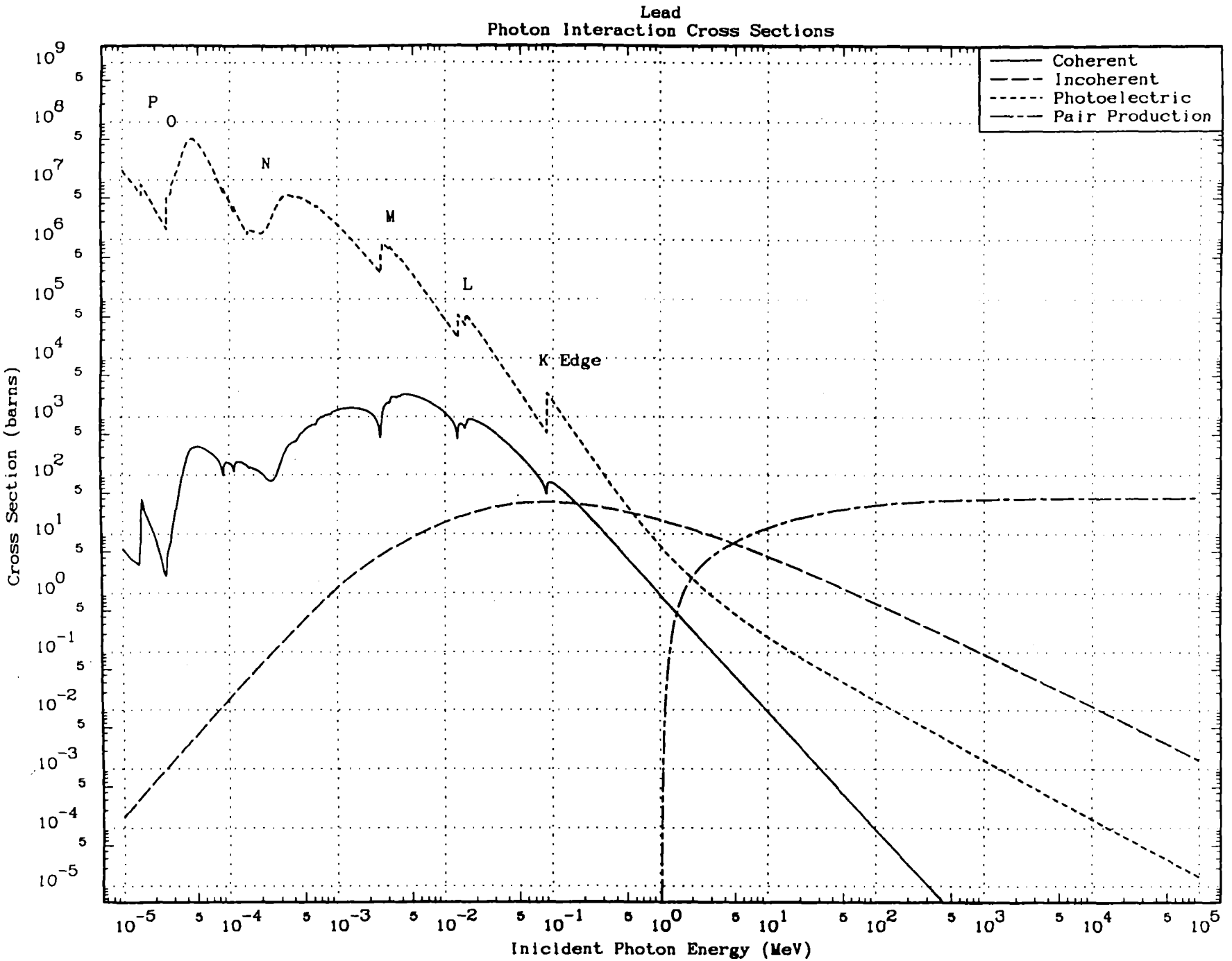
Figure Captions

1) lead photon interaction cross sections

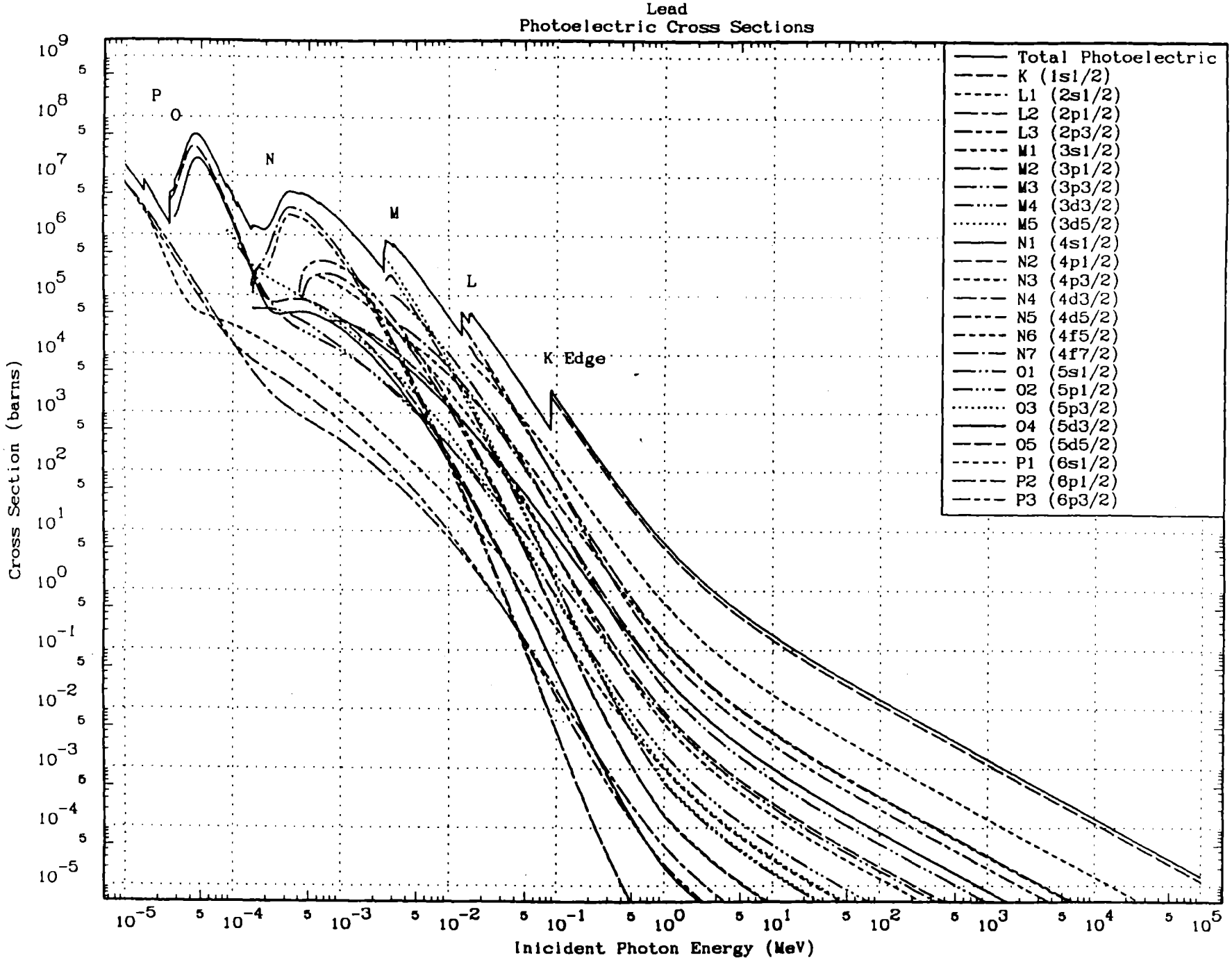
2) lead photoelectric subshell cross sections

3) lead radiative and non-radiative emissions for a K shell vacancy

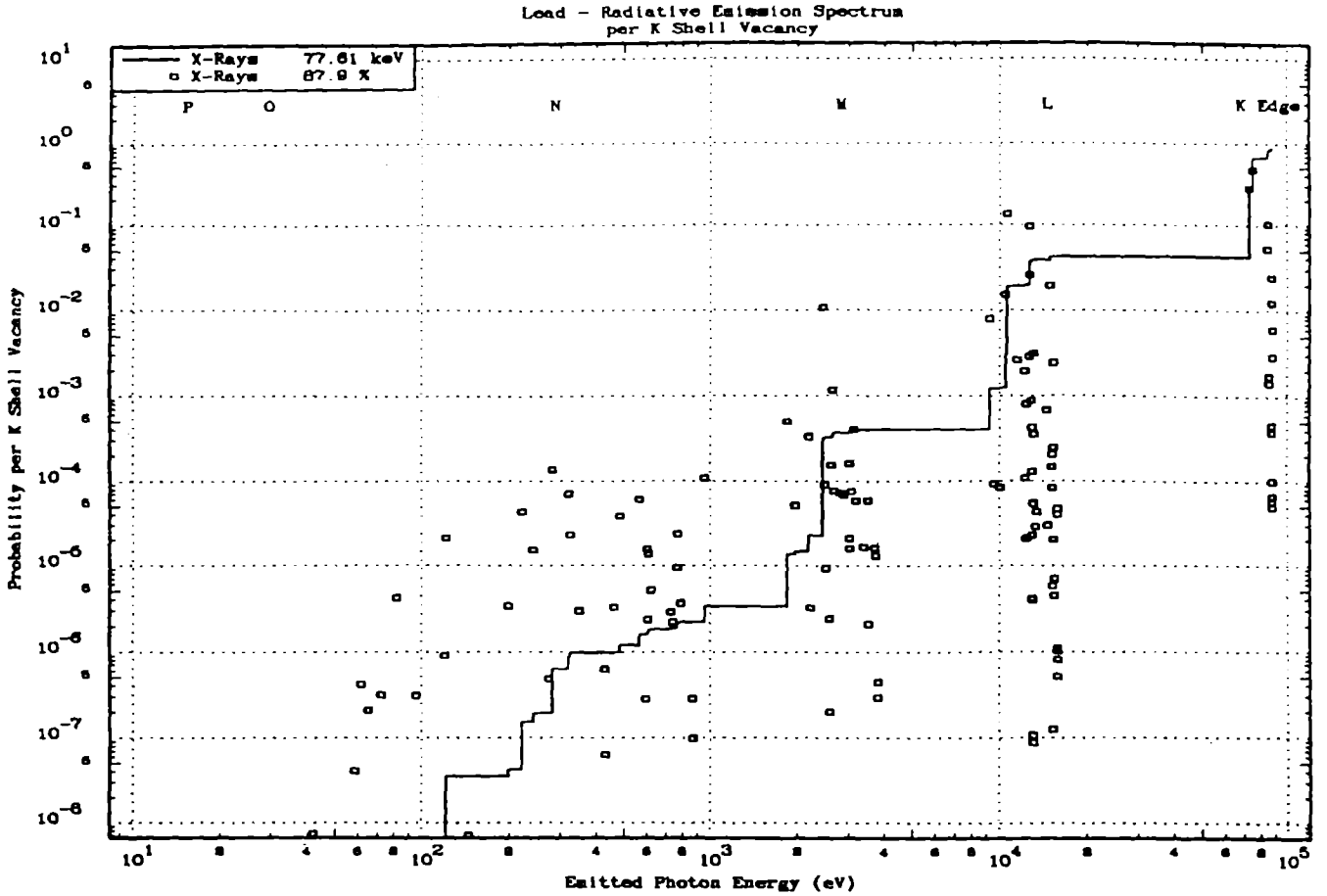
4) lead electron ionization cross sections

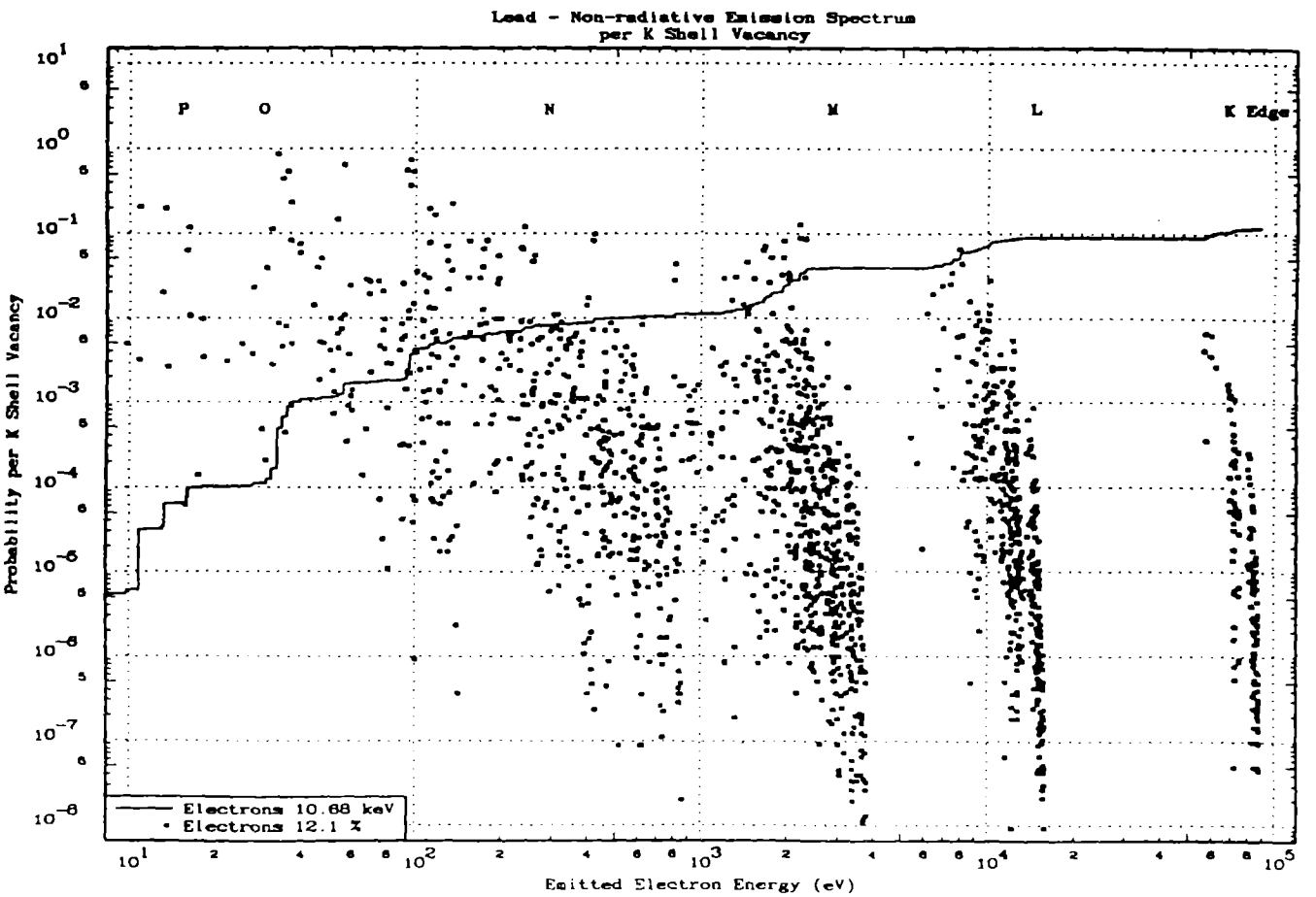


1) lead photon interaction cross sections

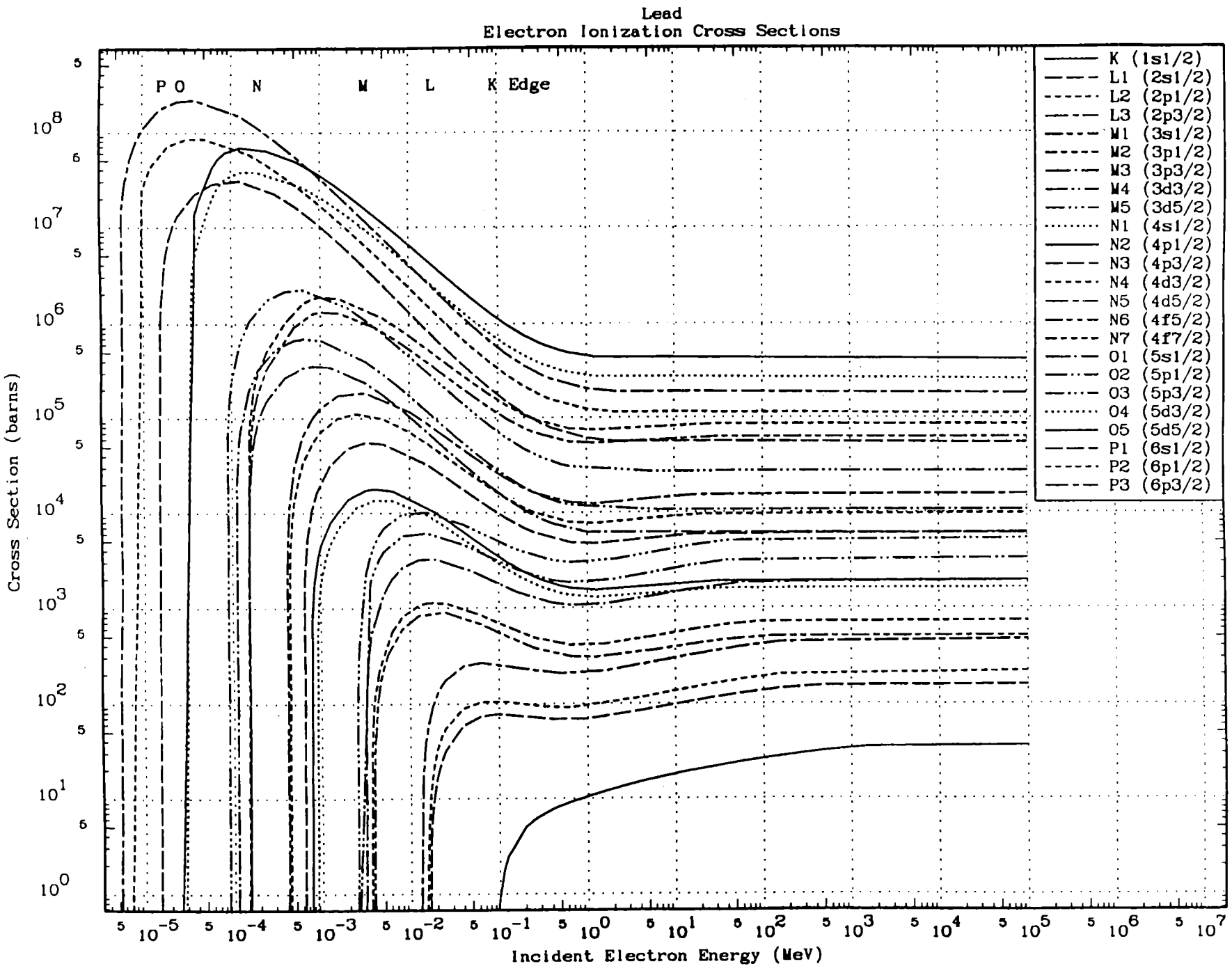


2) lead photoelectric subshell cross sections





...radiative emissions for a K shell vacancy



A) lead electron ionization cross sections